FTA Risk Management: Beta at Five….

Introduction…

Technical Issues

- **Key Modeling Issues…**
  - We have resolved most of the technical modeling issues associated with "top-down" or in FTA's case, the "range model", i.e. Beta modeling… normal development issues will continue to emerge such as validity of demarcation lines in the mitigation sequence (design versus requirements risk), definitional issues such as what is requirements risk?... assessing effectiveness of the model integrating all of the characterization data…
  - "Bottoms-Up" modeling ("sources of risk lists", "risk registers") does not seem to have progressed much in the last five years... we seem to lost track of our guidelines for testing adequacy of these models, running diagnostics on them... mapping them back into budgets to determine if they are efficient models and completely cover risk exposure… These models still don't use any standardized risk mitigation sequence and often the risks contained are "poorly stated" …mitigation in these models is therefore a complete elimination instead of a sequenced mitigation … Lastly, still a large lack of calibration data to demonstrate their accuracy compared to the top-down models…
- **Realized Risk Analysis**
  - Once a risk baseline has been established the next step is measure the effectiveness and efficiency of the grantee's project office in mitigating project risk… this poses a number of technical challenges of analyzing previous forecasts in the middle of an ongoing data stream… again, there has been work in this area on the top-down modeling but none in the bottom up area…

Management Issues

- **Tradeoffs**
  - Industry still only offers a two part risk model (refer to Roberds 2006 article that described a two part risk model, "Base + Risk")… versus the three part FTA model such as that used in New Jersey and New York of "Base + Risk Calibrated Contingency + Risk Premiums/Discounts"
  - Still a challenge for agencies such as FTA to keep message focused on risk informed project management versus industry preference for risk based …
  - There is still much to be done in advocating for a process that integrates previous program experience such as TCRP studies and FTA's previous New Starts projects with project specific data generated by the grantee...
- **Monetizing the risk…**
  - Integrating FTA's beta modeling with the TCRP data arguably demonstrates that its grantees typically manage somewhere in the range of three to five dollars in risk for every one dollar in contingency … the industry currently argues this ratio is one for one which understates the risk exposure of these projects…

  - Top Down modeling such as Beta, offers a way to simulate a number of mitigation scenarios... which one is the one to use as a basis for determining the budget?... as noted in the attached PowerPoint materials .. looking back from 2011 to the first set of 2006 forecasts shows that the grantee's have traditionally mitigated into the 25% bid milestone and it can be argued that the EAC will probably fall into the 50-90th % range… It should be stressed however that this should be viewed as only an initial estimate of the monetizing of the risk exposure for the project and not a "cookie cutter" tool for determining project contingency…
- **Management Capacity**
  - One bright spot is the conceptual development in the area of technical capacity and capability since 2005… our ability to analyze management capabilities and then break that down into analysis of implementation of better/best practices, specific mitigation capacities and lastly integrated decision making has vastly improved as a result of MWAA's Dulles, NJT's ARC and MTA's Eastside Access and Second Avenue projects…
- **Risk Planning and Program Development**
  - FTA in the area of the detailed application of risk management has a wealth of experience and track record that is unrivaled in the US Federal Government… compare our modeling and contingency knowledge to other agencies such as DOD, USACE, EPA, DOE/Waste Management, etc…
  - On the other hand, FTA has not of yet developed policy guidance and management process to the level of the other agencies
  - Challenge of integrating risk and contingency management and reporting ... the real challenge of contingency and estimate at completion (EAC) forecasting

Policy Issues

- **Communication, Communication, Communication…**
  - Policy Makers and Non-technical managers must have risk baseline data that is relatively stable over time and intuitively presents the "same picture" as a reference frame… they must be able to manipulate data within that baseline to determine for themselves the relative sensitivity of cost and schedule to the disclosed risk groups or "risk drivers"… the model must boil the statistical/probability exercise into a set of factors with consequences that be used by the policy makers to discuss the project issues and often negotiate complex/critical project decisions with external parties/congressional stakeholders… the consistency of that material and staff's explanation of the data directly relates to the perceived value the process offers…
  - The integrity of the MWAA Dulles and NJT ARC baselines was a critical factor in the acceptance by these individuals of staff recommendations as FTA went thru the critical decision process associated with funding these two projects…

I could talk on and on about this… but I close on the thought that it has been a pleasure to be a part of this effort…

Mike OConnor/TRO-02 Sr. Risk Manager … May 31,2011

FTA's risk process has evolved over the years from simple applications of industry standard techniques such as Monte Carlo simulations based upon grantee determined contingency levels with limited analysis of estimates and schedules. As demonstrated in various internal whitepapers, circa 2004-2006, the average risk forecast lasted a little more than year for projects lasting over eight years[i] and almost always was lower by substantial margins from the actual costs; mitigation opportunities were basically choice menus that had a ninety day planning horizon.

In late 2005, TPM restructured the risk assessment tools to recognize past weaknesses and take advantage of lessons learned in previous assessments. The result was a realization that three problems had to be solved; first was to resolve issues in the underlying estimate and schedule that had nothing to do with external risk factors such as stakeholders, second, the lack of a risk modeling process that was substantially more robust than the earlier models and last, lack of guidance on developing more extensive and detailed mitigation measures. Although these points are still in valid in 2011, what was not realized then in 2005 was a fourth problem (or a logical consequence of the third) which was the role of grantee management in mitigating risk. Lastly, the concept of a business model was not understood.

> *The fundamental questions in any risk assessment then are how much risk is the project exposed to; and given management's capacity to mitigate that risk; how much of that risk should be monetized into the budget or BCE?*
>
> *The answers to that proved to be (1) availability of credibly analyzed industry cost data[ii] which became the basis of FTA's contingency metrics, (2) improved tools for analyzing grantee's estimates and schedules to correct underlying problems with escalation, construction indirects, design and construction management and real estate costs; (3) and a basis for assessing the grantee's organization's ability to mitigate project risk.*

Following the development of this new framework in early 2006, several new starts projects had risk baselines established for them, including MTA's ESA and SAS projects, although prior to development of the contingency metrics, analysis tools or management capacity insights mentioned above. The first project to start down this path was the Entry into FD review for MWAA/WMATA's Dulles MOS-1 project. FTA management directed an evaluation of the grantee's management capacity and its ability to mitigate risk. This created the impetus to develop a separate database of projects which overlapped the TCRP study but was analyzed over time using the new RM principles to develop an understanding of how successful FTA grantees have been in mitigating risk (i.e. avoiding or containing cost growth) from entry into FD to revenue service. Of these 35 NS projects, 15 were "megaprojects" with significant geotechnical and environmental scope in urban areas over the past 25 years with an average cost growth of approximately 110% (Entry into FD to RSD, net of contingency, YOE$s)!…

- *For SAS, this would mean a $ 7.5bn project[iii] versus the FFGA BCE of $4.05bn and ETPC of $4.98bn.*
- *For ESA, this would mean a $ 7.56bn project [iv] versus the FFGA BCE of $6.35bn and EPTC of $8.11bn.*

In this thirty-five project dataset, the average cost growth of the five highest risk projects[v] for FTA was 155%, say 150%, or 2.5 times the Entry into FD budget for the project (again net of contingency, YOE$s).

- *For SAS, this would mean a $8.9bn (mean, YOE$S) project versus the FFGA BCE of $4.05bn and ETPC of $4.98bn.*
- *For ESA, this would mean a $ 9bn project versus the FFGA BCE of $6.35bn and EPTC of $8.11bn.*

One of the striking observations is that upon entry into FD, both projects had approximately the same budget base of $3.6bn (YOE$s, net of contingency) for ESA in Q4 2001 and SAS in Q1 2006. The immediate conclusions of this analysis are that MTA's SAS project is either less risky or better managed than the average new starts project[vi] while the ESA project is to some degree more risky than the average new starts project[vii]. The assessment of management has be seen in the context of stakeholder management and that the ESA project called for engaging a vastly more complex set of stakeholders than SAS. This required a larger degree of management capacity from

ESA than SAS which as performance to date has shown ESA has not been able to achieve. If ESA management had been managing the SAS project, the results and performance to date would probably be the same.

> *In simple terms, ESA confronts a set of more difficult stakeholders and greater geotechnical risk than SAS does and the cost performance data at the project level as well as FTA's historical experience bears that out.*

In terms of the contingency metrics, analysis tools or management capacity insights discussed above, where are the projects in 2011 and what are their prospects for cost performance thru revenue service in the later part of this decade (2016-2020)?

The ESA project was reviewed several times, first by the US Army Corps of Engineers in 2002 and then using several risk models in the 2004 thru 2007 period (see attached charts). In 2004, LIRR retained the services of an outside risk consultant who forecast a project cost with an estimate that there was a.."99.9% probability that actual will materialize between $5,395 and $6,744 million." [viii] That same year, the FTA PMO conducted a risk review[ix] and estimated the risk exposure to be $5bn to $7bn. In 2006, the FFGA review by the FTA PMO estimated a range of $6.19bn to $8.93bn[x]. In all of these cases, underlying issues with contingencies and estimates were present and in light of the 2009 reviews were not adequately addressed.

> *Looking back to the entry into FD budget for ESA ($5,265mm,YOE$s in Q3 2002) in light of the metrics and tools available in 2011 shows three large problem areas that would have been picked up in 2004 if that experience had been available.*
>
> *The first in escalation has been a problem for the project discussed by the PMO in 2001 as well as part of the USACE study. Using MTA's own data for escalation from 2001 thru 2008 means that this impact along could have added as much as **$800mm** (YOE$s) to the budget.*
>
> *The second in geotechnical risk was also a problem for ESA. At the time of early final design for ESA in 2005[xi], the geotechnical risk premiums had not been developed and no change was made to reflect this known risk. In 2009, the FTA PMO would estimate this cost to **be $700mm** of which $500mm had already been realized. NJT's ARC project would also validate the risk premium approach for geotechnical in the 2010 review validating the 2008 estimates, but that was not available for ESA in 2002.*
>
> *Lastly, the contingency defined in the MTA budget was $234mm or 4% [xii]. This is well below the current practice of establishing contingencies either by TRB data or FTA RM practices (MWAA Dulles had an FD contingency of 28% and NJT ARC had 22%).Adjusting this to the same % as NJT's ARC would increase the contingency by **$875mm!***

Other adjustments based upon TRB data released in 2006 for design, CM and real estate would have driven this 2002 budget higher but with these three items alone, the budget would have increased by $2,375mm to $7,640mm, close to MTACC's current working budget value for ESA of $7,791mm[xiii] first established in 2009!

A similar case could be made for SAS, the entry into FD contingency was only $320mm or 9%, but escalation was only going to be an estimated **$150 mm** (3% of the project versus 10% for ESA) and the geotechnical risk was estimated by the PMO in 2009 to be only **$230mm**. Adjusting the contingency up to the equivalent of NJT's ARC at 22% would have added another **$461mm**[xiv] **As in ESA, other adjustments based upon TRB data released in 2006 for design, CM and real estate would have driven this 2006 SAS budget higher but with these three items alone, the budget would have increased by $841mm to $4,721mm, slightly larger than MTACC's current working budget value for SAS of $4,673mm[xv] first established in 2009!**

In conclusion, several things can be said in 2011 for ESA and SAS, first, the ranges established in 2009 are based upon sound metrics and analysis and should be valid well into the future if not to revenue service for both projects; second, if these metrics and analysis had been in place in 2001 and 2006, ESA and SAS would likely have been more realistically budgeted; thirdly, management capacity is a major risk factor largely in its ability to engage stakeholders, often driving 10-25% cost increases into the project and lastly, any major project currently in FTA's portfolio that doesn't recognize these principles in its budgets, escalation and contingencies is at peril.

[i] TRCP G-07 (2006) average NS project is 96 months.

[ii] Following the 2006 period, TRB published an extensive set of cost data that could be used in FTA's risk analysis program. First, it published the G-07 study which gave FTA the analytical framework for its current phase specific, contingency targets. Then in 2010, it published G-11 which analyzed FTA projects for soft costs such as design, construction management, force account and real estate.

[iii] (1.0+1.1=2.1 x $ 3.56bn) base in 2006 for $3.88bn budget , SAS Rev 4, 2014 RSD)!...

[iv] (1.0+1.1=2.1 x $ 3.6bn) base in 2002 for $4.35bn budget, ESA, 2012 RSD)!...

[v] Members of this set include MBTA's South Boston piers project, PAAC's North Connector project and based upon current projections, MTACC's ESA project…

[vi] The program mean cost of $ 7.56bn is greater than the SAS FFGA BCE of $4.05bn or the ETPC of $4.98bn.

[vii] The program mean cost of $ 7.56bn is greater than the SAS FFGA BCE of $4.05bn or the ETPC of $4.98bn.

[viii] Decision Sciences Corporation/Curran report to LIRR dated May 20, 2004, page 7 of 19.

[ix] This was conducted using Monte Carlo risk registers without the formal characterization methods performed today as part of the PG3X, now OP3X spot reports ..such has the scope, schedule and cost reviews…

[x] 2006 Urban risk model using the 30% bid/FFGA award mitigation phase estimate and the P50-P90 estimates

[xi] Rev 2, June 24, 2005 of the ESA SCC workbook), the geotechnical scope as defined by SCC 10.6($393mm), 10.7($1,254mm), 20.3($804mm), had a total of $2,451mm ($2005, YOE adjustment to 2008 at 1.06 per rev 3 SCC workbook) or $2,598, say $2,600 in 2008$s).

[xii] ESA Entry into FD budget: Grand total in Base Year $s was given as $4,873mm less a disclosed contingency value of $234mm which leaves a value of $4,639mm, 2002$s ,net of contingency. A YOE$s, net of contingency was derived at $5,030mm (5,264 less 234) again YOE$s, 2012 RSD)

In this 2002 model the YOE adjustment value was not identified, but imputed from the data gives 1.0802 versus the 1.2490 using MTA's 2007 data to go from 2002$s to 2008$s. This is a difference of 17%, or **$785mm**!

[xiii] This ESA Current working budget figure was incorrectly stated in the earlier draft. It has now been corrected to the value given in the MTACC ELPEP.

[xiv] From 2009 PMO analysis in PG-47…

The contingency is calculated as follows (1) 13% of $3,552mm, is $460mm .. so .22 x $3,552 gives a total of $781mm less the ingoing contingency of $320mm gives an increase of $461mm,

[xv] This SAS Current working budget figure was incorrectly stated in the earlier draft. It has now been corrected to the value given in the MTACC ELPEP.

OP53 overlay on 2006 PG40 Beta Model

- OP53 risk model works from an optimistic risk forecast to an increasingly pessimistic risk forecast in a tighter focus that the OP40 model.
- OP40 and OP53 both work off of a base. The difference is that the OP40 base is “stripped” of contingency and adjusted to reflect a most optimistic estimate … OP53 similarly “strips” the contingency but is not further adjusted to develop an optimistic estimate …
- Both models then add back in budget to correct for mechanical errors, inconsistent escalation rates, etc.

OP53 overlay on 2006 PG40 Beta Model

- OP53 and OP40 are calibrated models that work of different assumptions and as demonstrated above, bases. Given that they both predict total cost for the project;
  - They should intersect at some set of mitigation milestones in the OP40 model which forecasts a longer timeline than OP53.
- Therefore, OP40 and OP53 should converge from their different bases into a zone of agreement somewhere in the middle of OP40’s mitigation milestones and then diverge as OP40 continues to forecast mitigation improvement while OP53 is constrained by the FTA past experience to a practical “limit” of mitigation effectiveness.

2010 OP53 overlay on 2006 PG40 Beta Model for NJT ARC

	10th percentile	50th percentile	90th percentile [Highest Risk; Largest Severity]
Entry into PE *(Assessed by FTA PMO in 2006)*			
[Q1 2006, 2006 plan]	$8.61bn	$12.33bn	$16.04bn
Entry into FD *(Assessed by FTA PMO in 2006)*			
[Q4 2007, 2006 plan]			
[Q1 2009A]	$8.18bn	$10.85bn	$13.51bn
25% Bid - FFGA Award *(Assessed by FTA PMO in 2006)*			
[**Q4 2010]**	$7.92bn	$9.70bn	$11.49bn
50% Bid – 30% Constructed *(Assessed by FTA PMO in 2006)*			
[Q3 2010, 2009 PEP]			
[Q4 2012, Rev 11 2010]	$7.56bn	$8.57bn	$9.57bn
100% Bid/ 80% Constructed *(Assessed by FTA PMO in 2010)*			
[Q1 2014, 2006, 2008 FD plan, 2009 PEP]			
[**Q2 2014, Rev 11 2010]**	$9.10bn	$9.97bn	$10.84bn
	[Lowest Risk; Lowest Severity]		

2010 OP53 overlay on 2006 PG40 Beta Model for NJT ARC

10th percentile | **50th percentile** | **90th percentile [Highest Risk; Largest Severity]**

Entry into PE *(Assessed by FTA PMO in 2006)*
[Q1 2006, 2006 plan] $8.61bn $12.33bn $16.04bn

Entry into FD *(Assessed by FTA PMO in 2006)*
[Q4 2007, 2006 plan]
[Q1 2009A] $8.18bn $10.85bn $13.51bn

25% Bid - FFGA Award *(Assessed by FTA PMO in 2006)*
[**Q4 2010]** **$7.92bn**

$9.70bn **$11.49bn**
2010 PreFFGA review is $9.77bn to $12.71bn
2009 entry into FD is $9.1bn reduced to $8.7bn
2008 PG46 Risk Range is $9.1bn to $12bn

50% Bid – 30% Constructed *(Assessed by FTA PMO in 2006)*
[Q3 2010, 2009 PEP]
[Q4 2012, Rev 11 2010] **$7.56bn**

$8.57bn **$9.57bn**
2009 entry into FD is $9.1bn reduced to $8.7bn
2006 Entry into PE is $7.176bn

100% Bid/ 80% Constructed *(Assessed by FTA PM*
[Q1 2014, 2006, 2008 FD plan, 2009 PEP]
[**Q2 2014, Rev 11 2010]** $9.10bn $9.97bn $10.84bn
[Lowest Risk; Lowest Severity]

OP53 overlay on 2006 PG40 Beta Model for ESA

	10th percentile	**50th percentile**	**90th percentile** **[Highest Risk; Largest Severity]**
20% Bid/ FD **[Q2 2006]**	$6.71bn	$8.44bn	$10.18bn
30% Bid [?]/FFGA Award [**Q4 2006]**	$6.15bn	$7.54bn	$8.93bn
40% Bid – 20% Constructed [**Q4 2007]**	$6.00bn	$6.98bn	$7.96bn
100% Bid **[Q4 2010, 2006 plan]** [**Q4 2012] ….**	$5.78bn	$6.17bn	$6.57bn
75% Constructed **[Q4 2011, 2006 plan]**	$5.78bn	$6.17bn	$6.57bn

[Lowest Risk; Lowest Severity]

OP53 overlay on 2006 PG40 Beta Model for ESA

	10th percentile	**50th percentile**	**90th percentile** **[Highest Risk; Largest Severity]**
20%Bid/ FD **[Q2 2006]**	$6.71bn	$8.44bn	$10.18bn
25%Bid/FFGA Award [**Q4 2006]**	$6.15bn	$7.54bn **2009 FTA ETPC is $8.11bn** **2009 MTACC CWB is $7.79bn**	$8.93bn
40%Bid – 20% Constructed [**Q4 2007]**	$6.00bn	$6.98bn	$7.96bn
100%Bid **[Q4 2010, 2006 plan]** [**Q4 2012] ….**	$5.78bn	$6.17bn **2006 FFGA BCE is $6.35bn**	$6.57bn
75% Constructed **[Q4 2011, 2006 plan]**	$5.78bn	$6.17bn	$6.57bn
Revenue Service Date [Q4 2013]	$5.70bn **2004 FTA PMO RM est of $5B to $7B** **2002 Entry into FD is $5.27bn** **2001 100% PE estimate is $4.35bn**	$5.93bn	$6.16bn

OP53 overlay on 2006 PG40 Beta Model

	10th percentile	**50th percentile**	**90th percentile**
100% PE/EPE/FPE			**[Highest Risk; Largest Severity]**
[Q4 2004, 2002 plan]			
[Q1 2006], Rev 2? UP?	$4.08bn	$5.12bn	$6.16bn
Entry into FD			
[Q2 2006]	$4.04bn	$5.02bn	$6.01bn
Final Design			
[**Q4 2006]**	$3.99bn	$4.88bn	$5.76bn
FFGA Award			
[**Q4 2007]**	$3.94bn	$4.67bn	$5.40bn
50% Bid – 20% Constructed			
[Q4 2008, 2006 plan]			
[Q4 2010], Rev 4 UP53	$3.89bn	$4.54bn	$5.19bn
100% Bid			
[Q4 2010, 2006 plan]			
[**Q2 2013] Rev 4 UP53**	$3.75bn	$4.15bn	$4.56bn
	[Lowest Risk; Lowest Severity]		

OP53 overlay on 2006 PG40 Beta Model for SAS

	10th percentile	**50th percentile**	**90th percentile** **[Highest Risk; Largest Severity]**
100% PE/EPE/FPE **[Q4 2004, 2002 plan]** **[Q1 2006], Rev 2? UP?**	$4.08bn	$5.12bn	$6.16bn
Entry into FD **[Q2 2006]**	$4.04bn	$5.02bn	$6.01bn
10% Bid/Final Design [**Q4 2006]**	$3.99bn	$4.88bn	$5.76bn
35% Bid/FFGA Award [**Q2 2006, 2004 PE plan]**	$3.94bn	$4.67bn	$5.40bn
50% Bid – 20% Constructed **[Q2 2009, 2006 plan]** **[Q4 2010], Rev 4 UP53**	$3.89bn	$4.54bn	$5.19bn
100% Bid **[Q2 2008, 2004 plan]** **[Q4 2010, 2006 plan]** [**Q2 2013] Rev 4 UP53** **[Lowest Risk; Lowest Severity]**	$3.75bn	$4.15bn	$4.56bn

2011 OP53 tier 4 to 6 range is $4.7 to $5.7bn

2010 ELPEP ETPC for SAS is $4.97bn
2009 PG47 forecast range is $4.7bn to $5.2bn.

2007 FFGA BCE is $4.05bn
2006 Entry into FD is $3.84bn

Sound Transit ULink FFGA PG40 Beta Model (2006)

	10th percentile	50th percentile	90th percentile
100% PE/Entry into FD			**[Highest Risk; Largest Severity]**
[Q4 2006A],	*$1,475mm*	*$2,027mm*	*$2,580mm*
0% Bid/ 40% Final Design; [**Q4 2007, 2006 plan]** [**Q2 200.., 200… FFGA SCC]**	*$1,502mm*	*$1,893mm*	*$2,283mm*
60% Bid; 75% Final Design/ FFGA Award [**Q4 2008;2006 plan]** [**Q2 200…; 2006 FFGA SCC]**	*$1,476mm*	*$1,773mm*	*$2,071mm*
65% Bid – 25% Constructed - 85% Final Design **[Q4 2009, 2006 Entry FD Plan]**	*$1,453mm*	*$1,694mm*	*$1,934mm*
75% Bid – 50% Constructed - 90% Final Design **[Q4 2010, 2006 schedule]**	*$1,436mm*	*$1,622mm*	*$1,809mm*
80% Bid – 70% Constructed - 92% Final Design **[Q4 2011 Entry into FD 2006 plan]**	*$1,421mm*	*$1,563mm*	*$1,704mm*
	[Lowest Risk; Lowest Severity]		

Sound Transit ULink Budget/EAC History overlay on PG40 Beta Model (2006)

	10th percentile	**50th percentile**	**90th percentile**
100% PE/Entry into FD			**[Highest Risk; Largest Severity]**
[Q4 2006A],	*$1,475mm*	*$2,027mm*	*$2,580mm*
0% Bid/ 40% Final Design;			
[**Q4 2007, 2006 plan]**			
[**Q2 200.., 200… FFGA SCC]**	*$1,502mm*	*$1,893mm*	*$2,283mm*
60% Bid; 75% Final Design/ FFGA Award			
[**Q4 2008;2006 plan]**			
[**Q2 200…; 2006 FFGA SCC]**	*$1,476mm*	*$1,773mm*	*$2,071mm*
		2008 Revised FFGA BCE is $1,746mm	
65% Bid – 25% Constructed - 85% Final Design			
[Q4 2009, 2006 Entry FD Plan]	*$1,453mm*	*$1,694mm*	*$1,934mm*
	2007 40% FD is $1,614mm;		
	2006 entry into FD is $1,514mm;		
75% Bid – 50% Constructed - 90% Final Design			
[Q4 2010, 2006 schedule]	*$1,436mm*	*$1,622mm*	*$1,809mm*
80% Bid – 70% Constructed - 92% Final Design			
[Q4 2011 Entry into FD 2006 plan]	*$1,421mm*	*$1,563mm*	*$1,704mm*
	[Lowest Risk; Lowest Severity]		

PAAC NSC FFGA PG40 Beta Model (2006)

	10th percentile	**50th percentile**	**90th percentile**
100% PE			**[Highest Risk; Largest Severity]**
[Q3 2002A],	n/a	n/a	n/a
Entry into FD			
[Q2 2003A]	n/a	n/a	n/a
60% Bid/ 60% Final Design; **[2006 RM workshop id this as Q4 2005, but should be Q3 2005A]**			
[**Q4 2004, 2002 plan]**			
[**Q2 2005, 2006 FFGA SCC]**	*$415mm*	*$512mm*	*$608mm*
60% Bid; 80% Final Design/ FFGA Award **[2006 RM workshop id this as Q2 2006]**			
[**Q2 2004;2003 plan]**			
[**Q2 2006A; 2006 FFGA SCC]**	*$409mm*	*$479mm*	*$548mm*
80% Bid(**E**) – 40% Constructed - 100% Final Design **[2006 RM workshop id this as Q1 2007, but should be Q4 2007]**			
[Q1 2007, 2006 FFGA SCC]			
[Q3 2008A,10/2008 PMO report]	*$398mm*	*$456mm*	*$513mm*
100% Bid –50% Constructed **[2006 RM workshop id this as Q1 2009]**			
[Q1 2009, 2006 FFGA SCC schedule]			
[Q… 20…], …	*$394mm*	*$438mm*	*$482mm*
100% Constructed; RSD **[2006 RM workshop id this as Q4 2010]**			
[Q2 2008 – Entry into FD 2003 plan;Q2 2011- FFGA RSD;]			
[**Q2 2012 current forecast]**	*$395mm*	*$426mm*	*$457mm*

[Lowest Risk; Lowest Severity]

PAAC NSC FFGA Budget/EAC History overlay on PG40 Beta Model (2006)

	10th percentile	**50th percentile**	**90th percentile** **[Highest Risk; Largest Severity]**
100% PE **[Q3 2002A],**	n/a	n/a	n/a
Entry into FD **[Q2 2003A]**	n/a	n/a	n/a
60% Bid/ 60% Final Design; **[2006 RM workshop id this as Q4 2005, but should be Q3 2005A]** [**Q4 2004, 2002 plan]** [**Q2 2005, 2006 FFGA SCC]**	*$415mm*	*$512mm*	*$608mm*
60% Bid; 80% Final Design/ FFGA Award **[2006 RM workshop id this as Q2 2006]** [**Q2 2004;2003 plan]** [**Q2 2006A; 2006 FFGA SCC]**	*$409mm*	*$479mm*	*$548mm*
80% Bid(**E**) – 40% Constructed - 100% Final Design **[2006 RM workshop id this as Q1 2007, but should be Q4 2007]** **[Q1 2007, 2006 FFGA SCC]** **[Q3 2008A,10/2008 PMO report]**	*$398mm*	*$456mm*	*$513mm*
100% Bid –50% Constructed **[2006 RM workshop id this as Q1 2009]** **[Q1 2009, 2006 FFGA SCC schedule]** **[Q… 20…], …**	*$394mm*	*$438mm*	*$482mm*
100% Constructed; RSD **[2006 RM workshop id this as Q4 2010]** **[Q2 2008 – Entry into FD 2003 plan;Q2 2011- FFGA RSD;]** [**Q2 2012 current forecast]**	*$395mm*	*$426mm*	*$457mm*

2011 EAC for NSC is $540mm

2006 Revised FFGA BCE is $435mm up from $393mm
2005 Initial FFGA BCE is $393mm;
2003 entry into FD is $393mm; 2002 Entry into PE is $385mm

HRT LRT FFGA
PG40 Beta Model (2006)

	10th percentile	**50th percentile**	**90th percentile**
100% PE			**[Highest Risk; Largest Severity]**
[Q2 2006]	**$**237mm	$280mm	$323mm
Entry into FD			
[Q4 2006;2006 SCC]	**$**234mm	$275mm	$315mm
…% Bid/ 50% Final Design;			
[**Q2 2007;2006 SCC]**	$233mm	$271mm	$309mm
40% Bid - 80% Final Design/ FFGA Award			
[**Q1 2008; ;2006 SCC]**	$224mm	$251mm	$279mm
100% Bid – 20% Constructed - 100% Final Design			
[Q2 2008;2006 SCC]	$211mm	$227mm	$244mm
100% Bid – 50% Constructed			
[Q3 2008;2006 SCC]	$204mm	$217mm	$230mm
90% Constructed; RSD			
[Q2 2009;2006 SCC]	$199mm	$208mm	$218mm
	[Lowest Risk; Lowest Severity]		

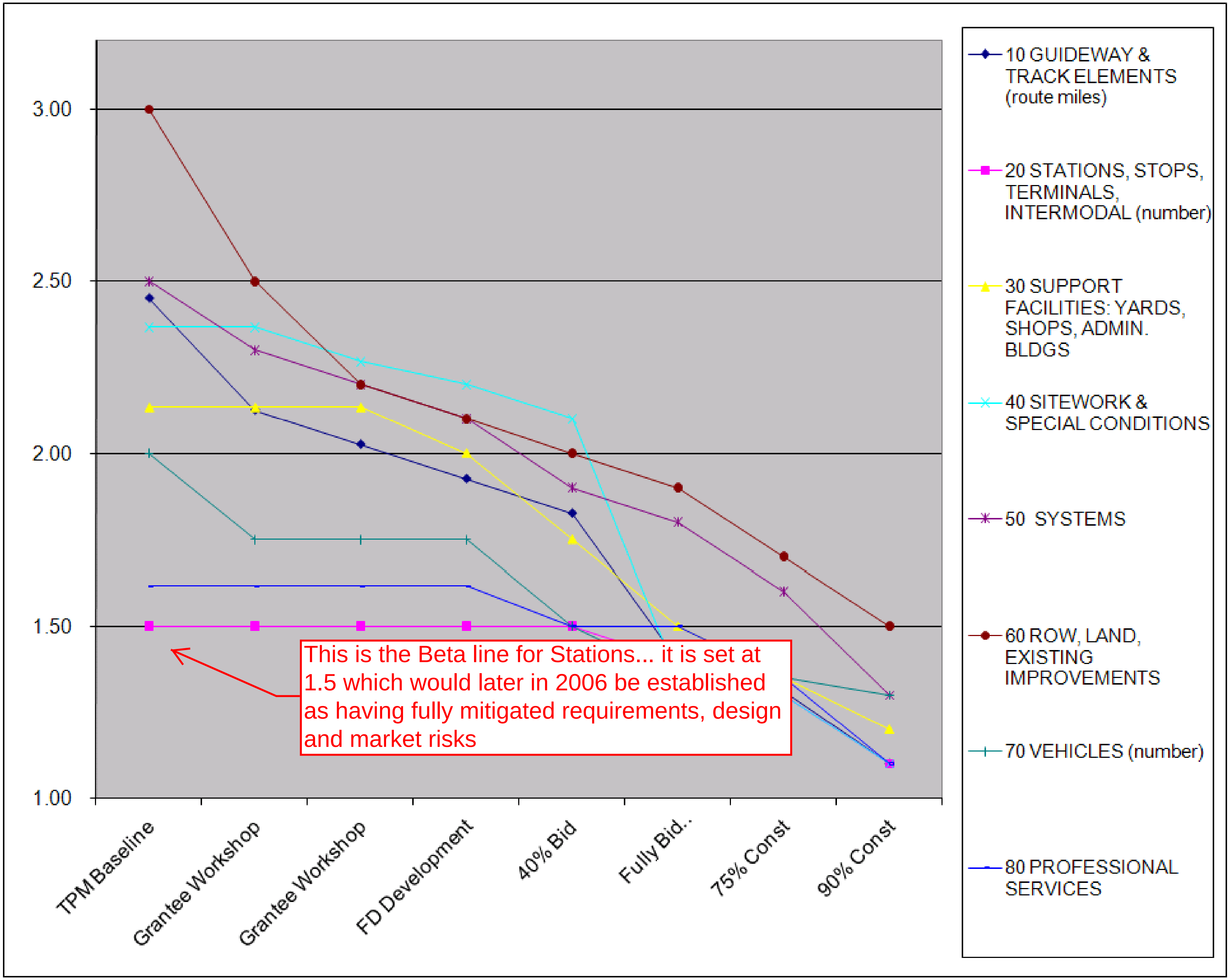
HRT LRT FFGA Budget/EAC History overlay on PG40 Beta Model (2006)

	10th percentile	**50th percentile**	**90th percentile**
			[Highest Risk; Largest Severity]
100% PE **[Q2 2006]**	$237mm	*$280mm*	*$323mm*
		2010 04 EAC for HRT is $334mm	
Entry into FD **[Q4 2006;2006 SCC]**	$234mm	*$275mm*	*$315mm*
		2009 04 EAC for HRT is $288mm	
…% Bid/ 50% Final Design; **[Q2 2007;2006 SCC]**	$233mm		
40% Bid - 80% Final Design/ FFGA Award **[Q1 2008; ;2006 SCC]**	$224mm	$251mm	$279mm
100% Bid – 20% Constructed - 100% Final Design **[Q2 2008;2006 SCC]**	$211mm	*$227mm*	*$244mm*
		2007 FFGA BCE for HRT LRT is $232mm	
100% Bid – 50% Constructed **[Q3 2008;2006 SCC]**	$204mm	$217mm	$230mm
90% Constructed; RSD **[Q2 2009;2006 SCC]**	*$199mm*	*$208mm*	*$218mm*

2006 Entry into FD BCE is $232mm up from $203mm
2005 100% PE budget is $203mm; RSD: Q32008
1997 Entry into PE is $210mm; RSD:2018;

[Lowest Risk; Lowest Severity]

Estimate Classification	Estimate Grantee	Estimate PMOC	Estimate Adjusted	p=10%	Risk Beta	p=90%	Mean	Std Dev
Percent Of Total	85.1%	14.9%	100.0%	-z[stand]=-1.2816		z(stand)=-1.2816		
10 GUIDEWAY & TRACK ELEMENTS (route miles)	$ 43,758,898	$ 7,665,120	$ 51,424,018	$ 51,424,018		$ 119,854,608	$82,901,235	$23,653,118
Drawings / Specifications	39,362,064	4,165,120	43,527,184	43,527,184	2.30	100,112,523	$69,591,339	$23,224,853
Schedule (Includes Escalation)	734,465	-	734,465	734,465	2.50	1,836,162	$1,237,920	$457,071
Design Report	-	-	-	-	2.50	-	$0	$0
GCs	3,662,369	3,500,000	7,162,369	7,162,369	2.50	17,905,923	$12,071,975	$4,457,272
Percent Of Total	92.1%	7.9%	100.0%					
20 STATIONS, STOPS, TERMINALS, INTERMODAL (nu	$ 4,757,828	$ 410,603	$ 5,168,430	$ 5,168,430		$ 7,752,645	$6,409,710	$792,891
Drawings / Specifications	3,402,493	410,603	3,813,096	3,813,096	1.50	5,719,643	$4,728,871	$752,779
Schedule (Includes Escalation)	97,876	-	97,876	97,876	1.50	146,815	$121,383	$19,323
Design Report	-	-	-	-		-	$0	$0
GCs	1,257,458	-	1,257,458	1,257,458	1.50	1,886,187	$1,559,457	$248,247
Percent Of Total	94.4%	5.6%	100.0%					
30 SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BL	$ 13,612,423	$ 811,556	$ 14,423,979	$ 14,423,979		$ 31,410,246	$22,288,545	$6,310,336
Drawings / Specifications	12,399,882	411,556	12,811,438	12,811,438	2.20	28,185,164	$19,923,134	$6,276,608
Schedule (Includes Escalation)	-	-	-	-	2.20	-	$0	$0
Design Report	-	-	-	-		-	$0	$0
GCs	1,212,541	400,000	1,612,541	1,612,541	2.00	3,225,082	$2,365,411	$651,560
Percent Of Total	130.8%	-30.8%	100.0%					
40 SITEWORK & SPECIAL CONDITIONS	$ 10,710,507	$ (2,520,039)	$ 8,190,468	$ 8,190,468		$ 18,863,412	$13,105,914	$3,276,397
Drawings / Specifications	4,659,979	979,961	5,639,940	5,639,940	2.30	12,971,862	$9,017,146	$3,009,310
Schedule (Includes Escalation)	126,676	-	126,676	126,676	2.50	316,690	$213,509	$78,833
Design Report	-	-	-	-		-	$0	$0
GCs	5,923,852	(3,500,000)	2,423,852	2,423,852	2.30	5,574,860	$3,875,259	$1,293,298
Percent Of Total	91.0%	9.0%	100.0%					
50 SYSTEMS	$ 22,709,504	$ 2,236,876	$ 24,946,380	$ 24,946,380		$ 62,365,949	$42,046,435	$13,347,786
Drawings / Specifications	19,965,636	1,226,686	21,192,322	21,192,322	2.50	52,980,804	$35,719,074	$13,188,366
Schedule (Includes Escalation)	388,957	-	388,957	388,957	2.50	972,394	$655,577	$242,055
Design Report	84,095	-	84,095	84,095	2.50	210,238	$141,740	$52,334
GCs	2,270,815	1,010,190	3,281,005	3,281,005	2.50	8,202,513	$5,530,044	$2,041,829


3.00
2.50
2.00
1.50
1.00
TPM Baseline
Grantee Workshop
Grantee Workshop
FD Development
40% Bid
Fully Bid..
75% Const
90% Const
This is the Beta line for Stations... it is set at 1.5 which would later in 2006 be established as having fully mitigated requirements, design and market risks
10 GUIDEWAY & TRACK ELEMENTS (route miles)
20 STATIONS, STOPS, TERMINALS, INTERMODAL (number)
30 SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS
40 SITEWORK & SPECIAL CONDITIONS
50 SYSTEMS
60 ROW, LAND, EXISTING IMPROVEMENTS
70 VEHICLES (number)
80 PROFESSIONAL SERVICES

Risk Assessment by Phase

The empirical parameter β can vary through project implementation and shall be estimated in conformance with the following:

At a β of 2.5, all requirements risks have been mitigated; β's below 2.5 imply increasing mitigation of design risk; β's above 2.5 imply increasing uncertainty associated with project requirements.

At a β of 2.0, all design risks have been mitigated; β's below 2.5 but above 2.0 imply increasing mitigation of design risk; β's above 2.0 imply increasing uncertainty associated with project design. Design risk β's cannot be greater than 2.5 and may reflect a need to increase the adjusted base rather than force a higher β.

At a β of 1.75, all market risks inclusive of bidding risk have been mitigated through the availability of a firm price/quote; β's below 2.0 but above 1.75 imply increasing mitigation of market/bidding risk or availability of increasingly reliable market data short of a project specific firm price; β's above 1.75 but below 2.0 imply increasing uncertainty associated with market risk; similarly β's transitioning through 1.9, 1.85, 1.8, etc. reflect the increasing availability of reliable market on the high end to more specific pricing data on the lower end. Market risk β's cannot be greater than 2.0 and may reflect a need to increase the adjusted base rather than force a higher β.

At a β of 1.5-1.35, all early construction risks composed of Geotechnical/Utility/major claims, usually associated with 20% complete, have been mitigated; β's below 1.7 but above 1.5-1.35 imply increasing mitigation of such risk; β's above 1.5-1.35 but below 1.7 imply increasing uncertainty associated with geotechnical/utility/claim risks.

The reason for the allowable variation of 1.5-1.35 is to reflect that certain elements such as guideway or systems require using β's of 1.5 for fully mitigated whereas simple LRT stations that are the equivalent of bus pads only require β's of only 1.35 to reflect full mitigation of such early construction risk.

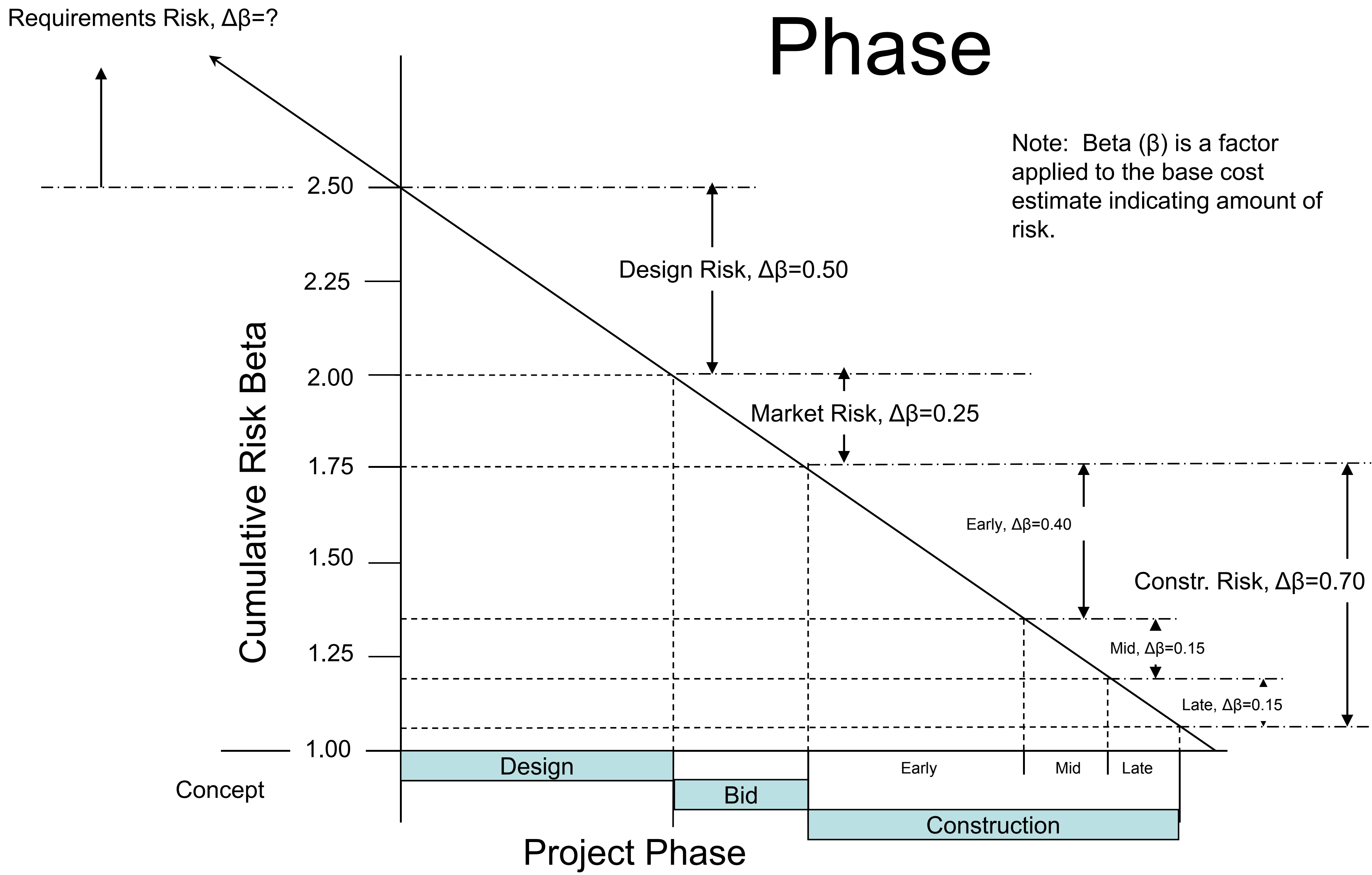
At a β of 1.35-1.20, all mid-construction risks inclusive of major claims, delays, impacts, etc., usually associated with 75% complete, have been mitigated; β's below this range imply increasing mitigation in the areas of normal change order activity.

The reason for the allowable variation is the same as before.

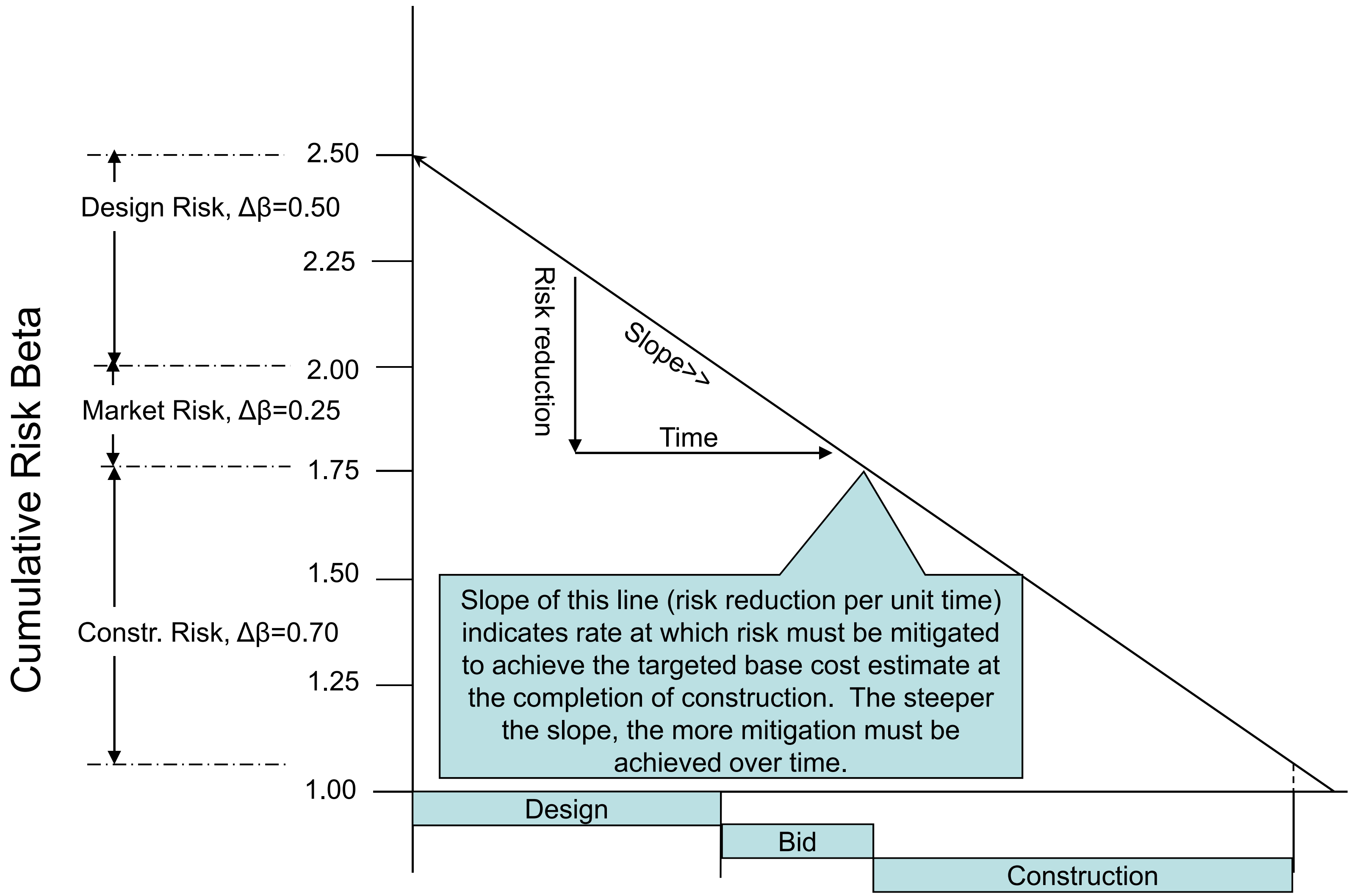
At a β of 1.15-1.05, all Start-up/Substantial Completion of construction risks, usually associated with 90%, have been mitigated; β's below this range imply increasing mitigation in the areas of start up and pre-revenue operations activity.

Risk Assessment by Phase

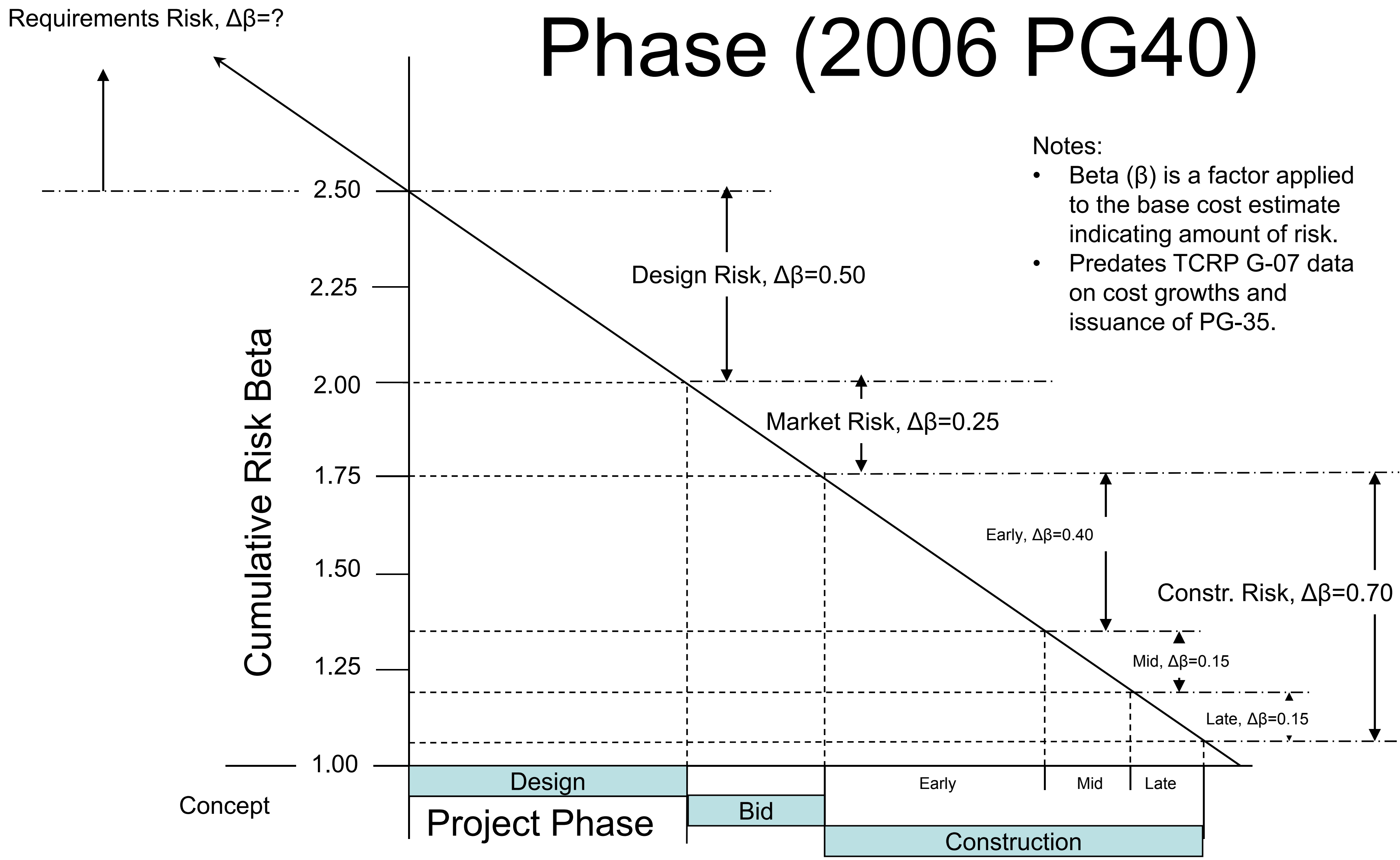
Note: Beta (β) is a factor applied to the base cost estimate indicating amount of risk.



Rate of risk mitigation



Risk Assessment by Phase (2006 PG40)

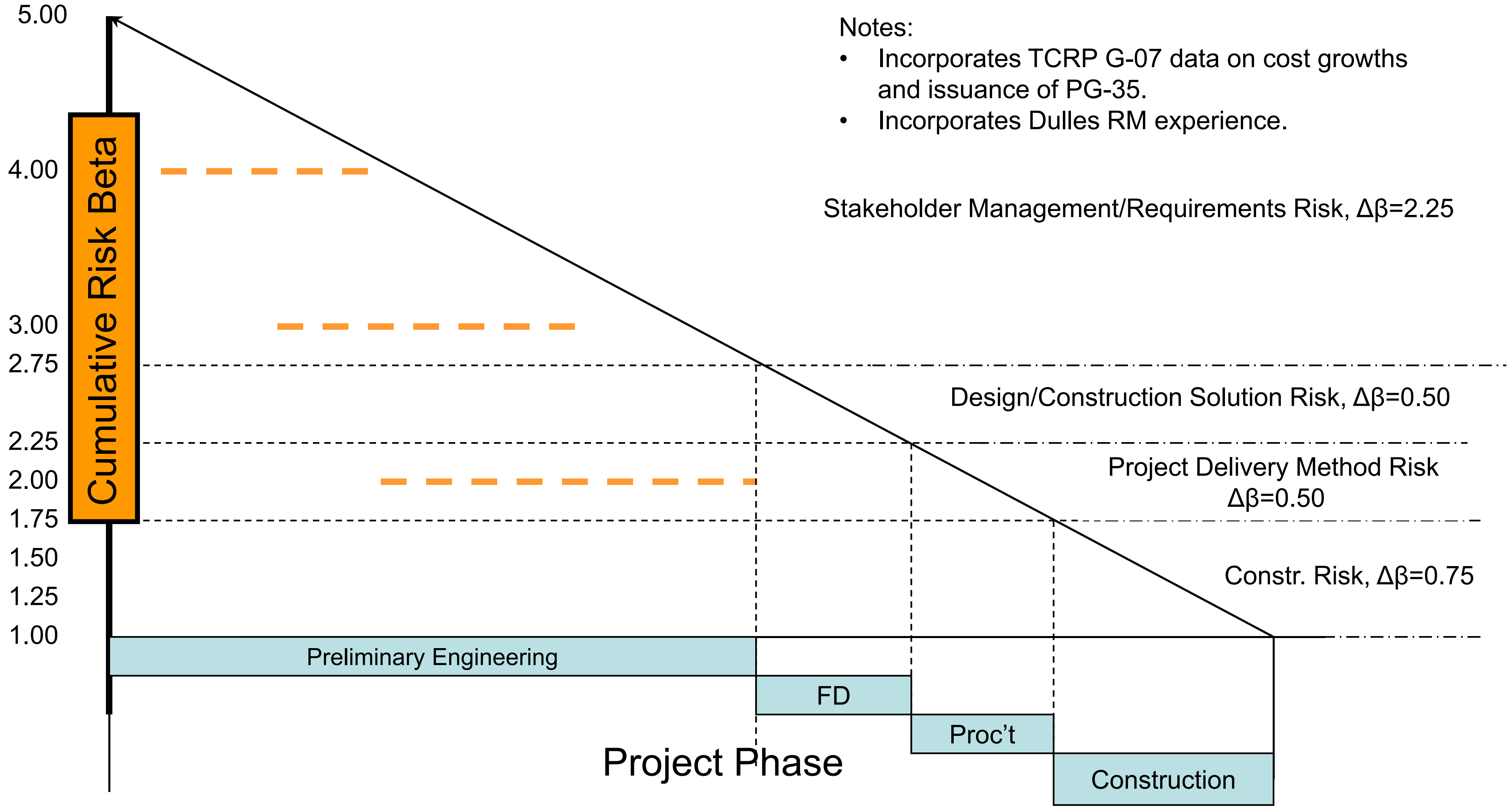


Notes:

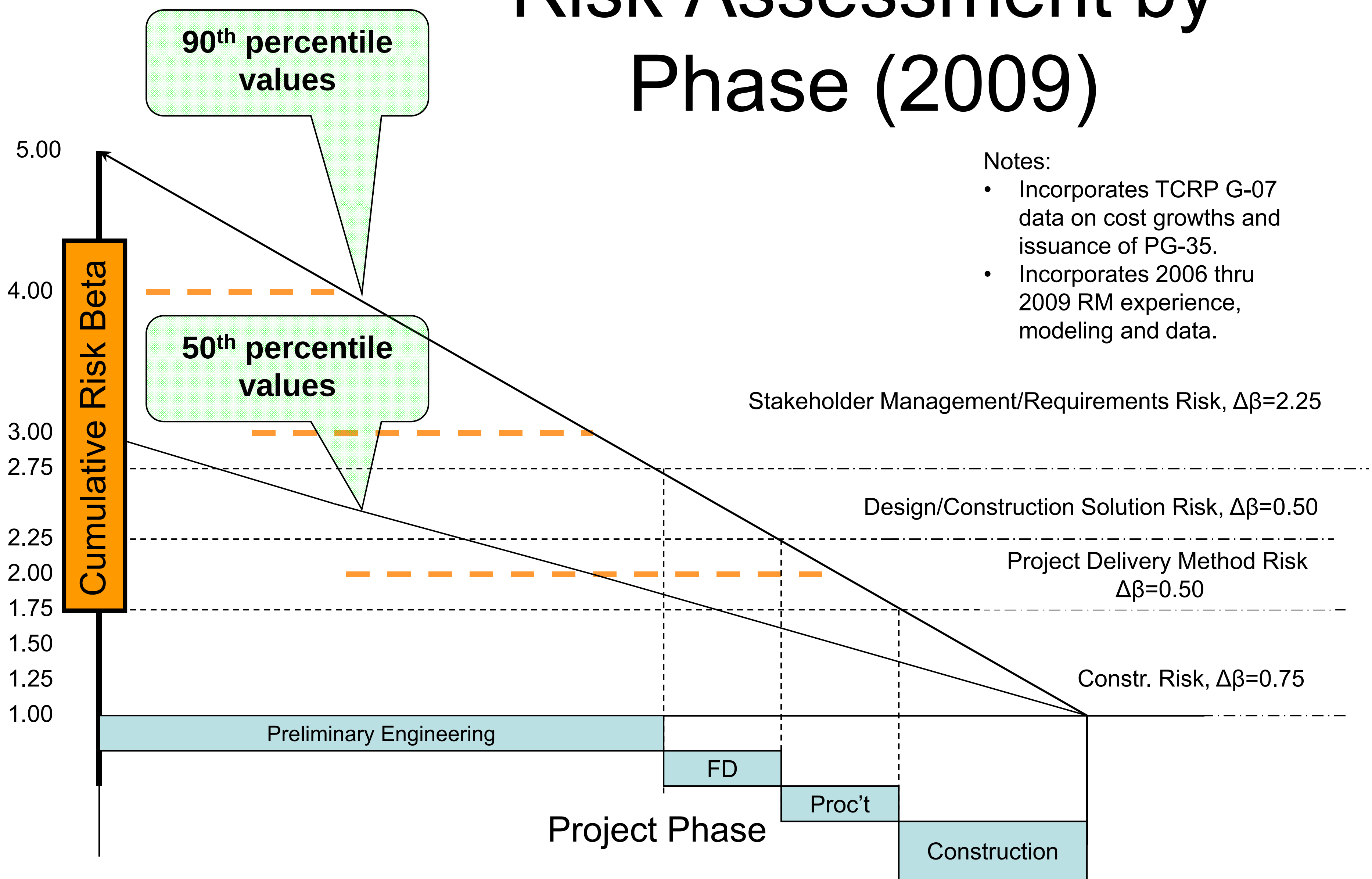
- Beta (β) is a factor applied to the base cost estimate indicating amount of risk.
- Predates TCRP G-07 data on cost growths and issuance of PG-35.

Risk Assessment by Phase (2009)

Notes:
- Incorporates TCRP G-07 data on cost growths and issuance of PG-35.
- Incorporates Dulles RM experience.

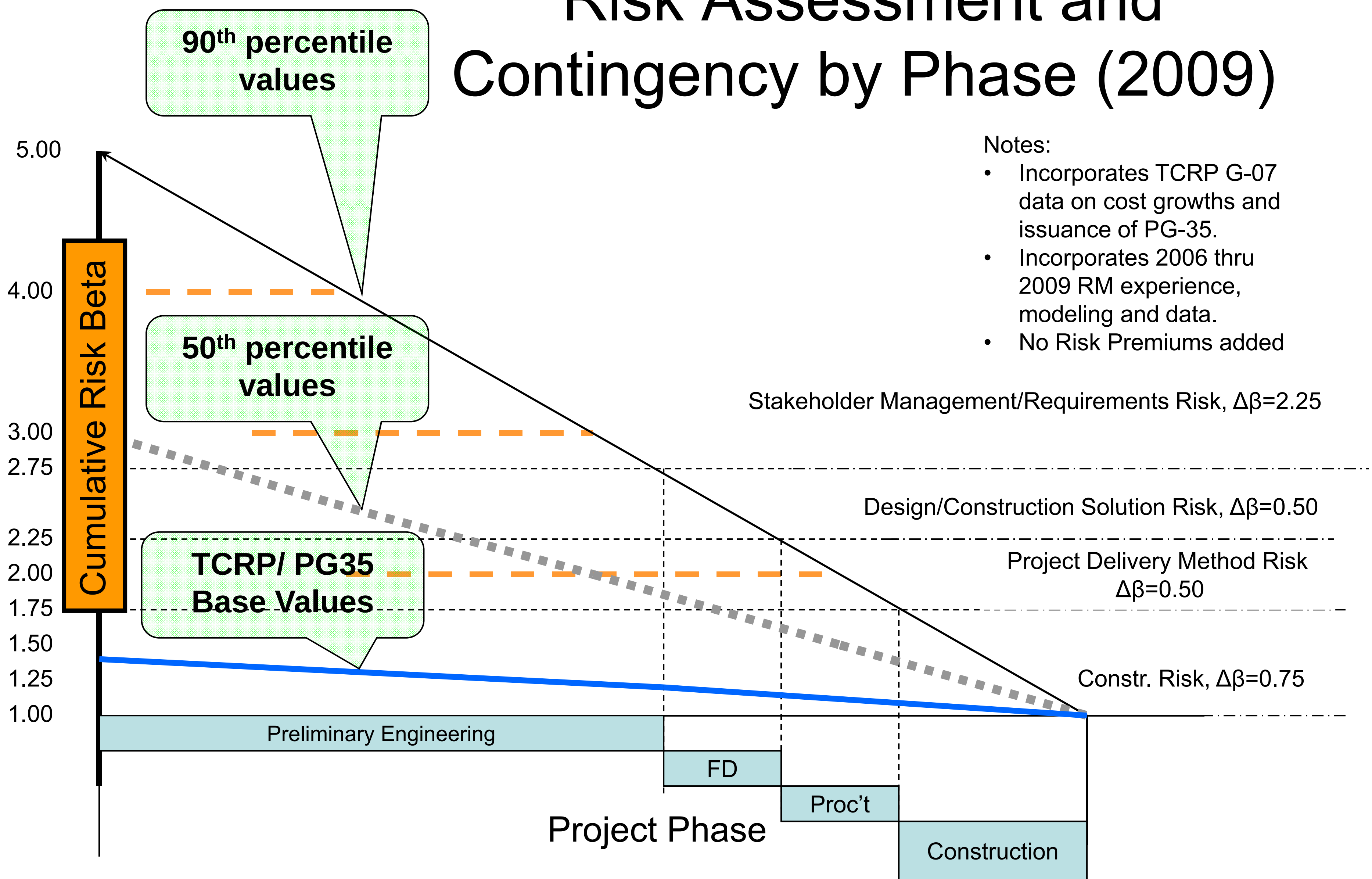


Risk Assessment by Phase (2009)



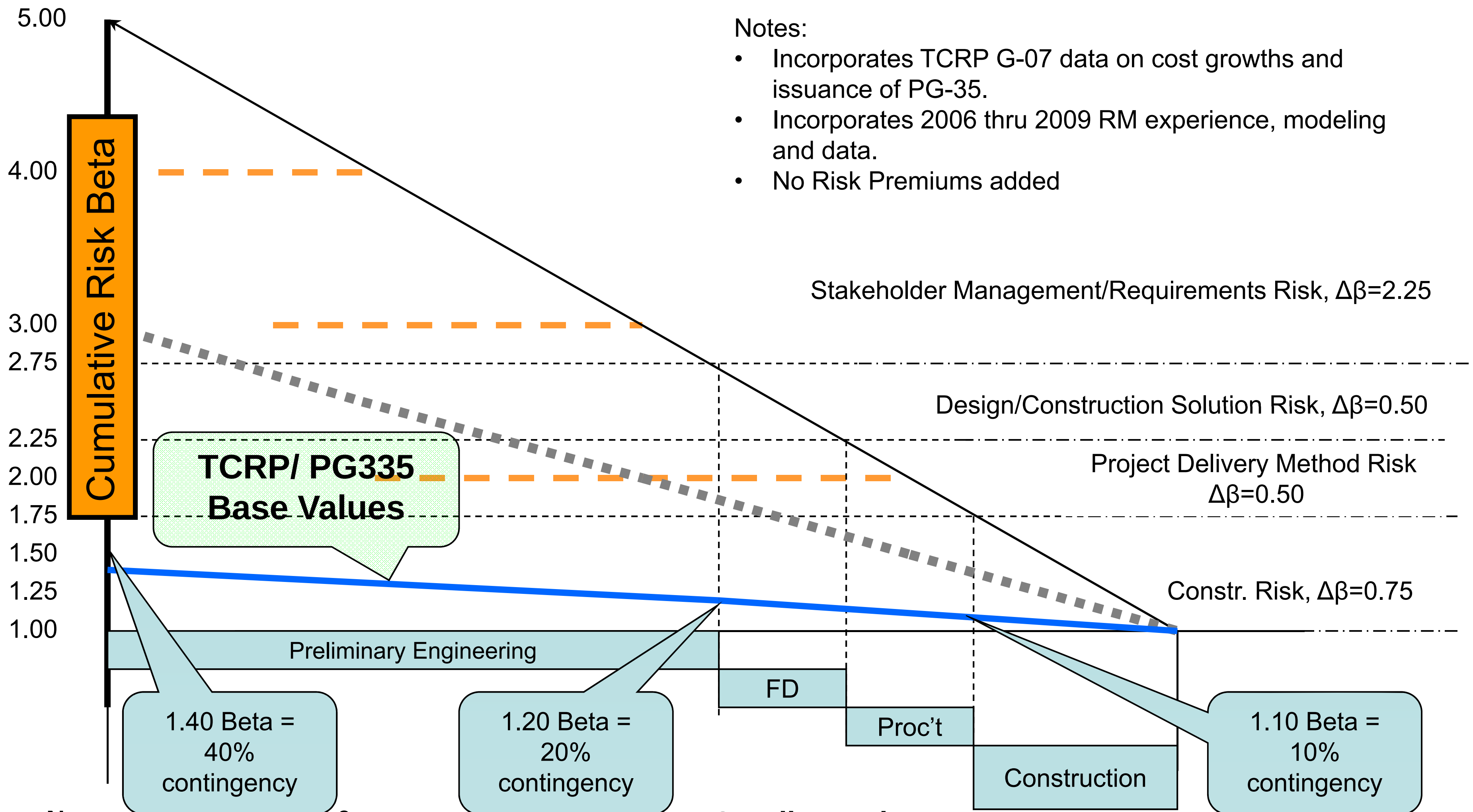
Notes:
- Incorporates TCRP G-07 data on cost growths and issuance of PG-35.
- Incorporates 2006 thru 2009 RM experience, modeling and data.

Risk Assessment and Contingency by Phase (2009)



Notes:
- Incorporates TCRP G-07 data on cost growths and issuance of PG-35.
- Incorporates 2006 thru 2009 RM experience, modeling and data.
- No Risk Premiums added

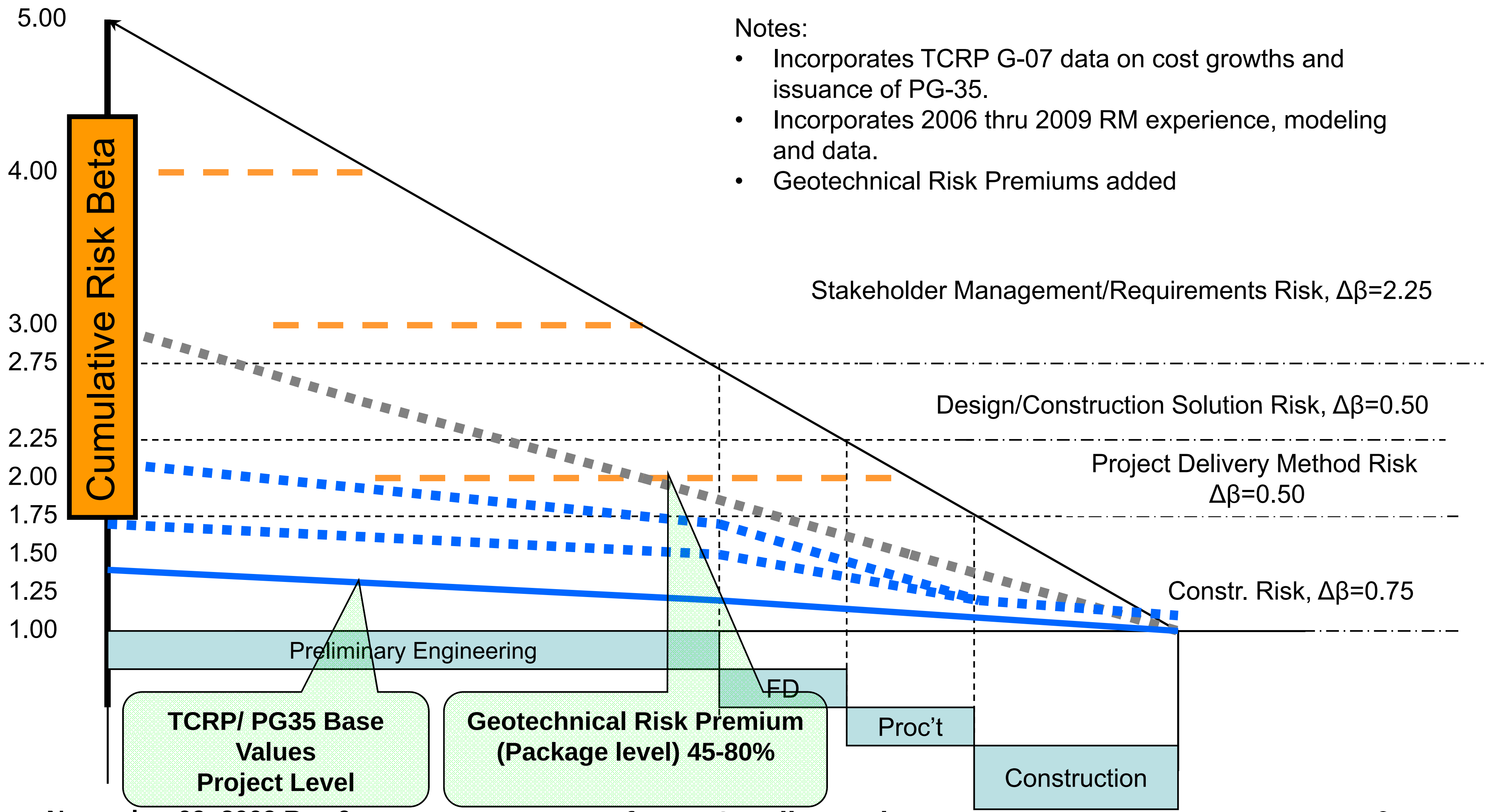
Risk Assessment and Contingency by Phase (2009) *Continued*



Notes:
- Incorporates TCRP G-07 data on cost growths and issuance of PG-35.
- Incorporates 2006 thru 2009 RM experience, modeling and data.
- No Risk Premiums added

Risk Assessment and Contingency by Phase (2009) *Continued*

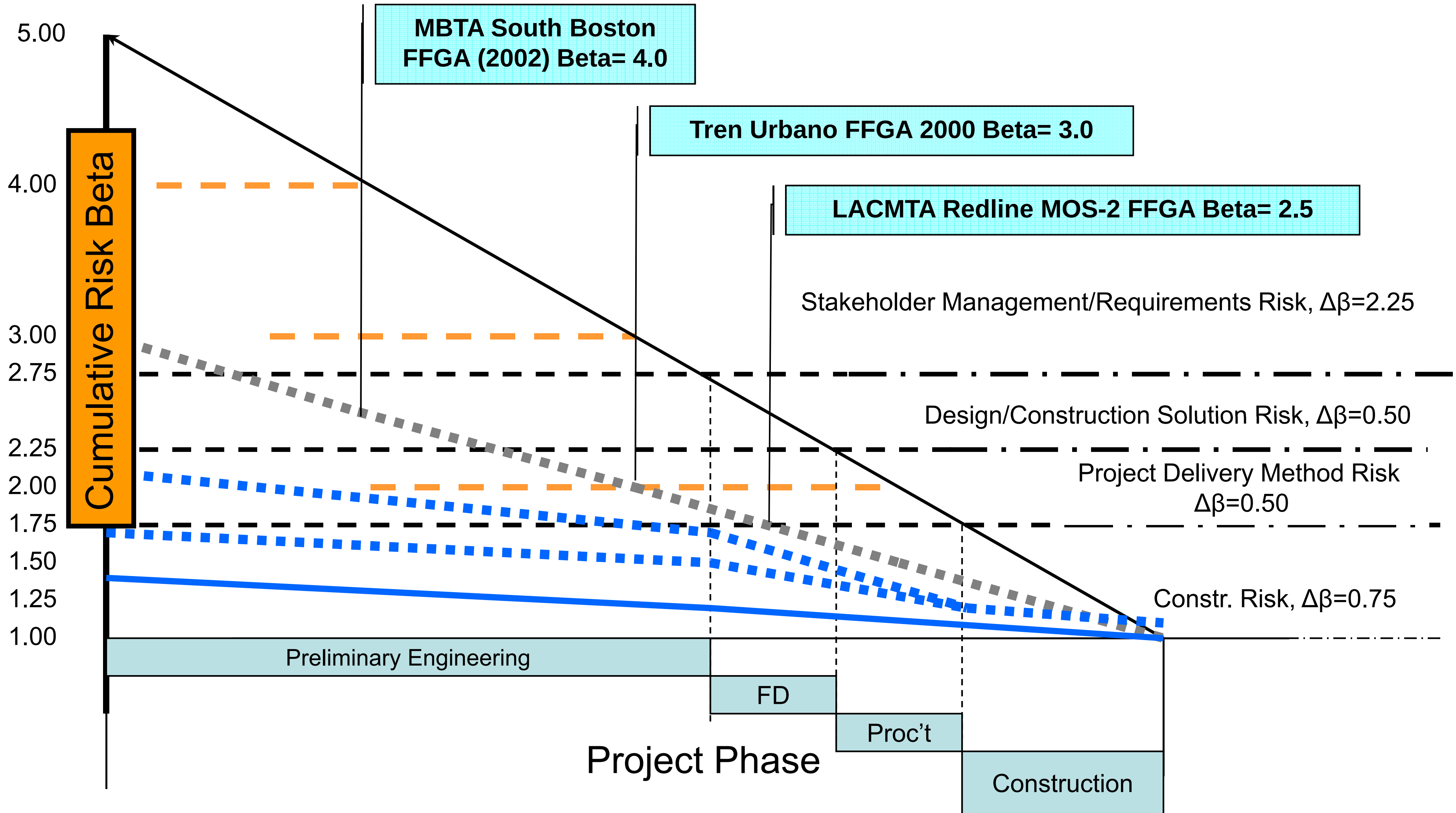
Notes:
- Incorporates TCRP G-07 data on cost growths and issuance of PG-35.
- Incorporates 2006 thru 2009 RM experience, modeling and data.
- Geotechnical Risk Premiums added



Introducing Program Experience

- Thru TCRP G-07, we have cost overrun experience that can be constructed into equivalent contingency and risk range data.
- The EAC, or final cost for the project, less the FFGA BCE net of contingency and financing gives an equivalent amount of contingency.
- If we had perfect knowledge at the time of the FFGA award, FTA would have presumably insisted on as the contingency amount.
- This would become the most likely estimate for the project or the 50th percentile.
- For the Beta model, the 50th percentile is approximated by 0.5β. Conversely, knowing the 50th gives the equivalent β by doubling the cost overrun and adding the base β of 1.0

Risk Assessment, Contingency and Program Experience by Phase (2009)



Risk Assessment, Contingency and Program Experience by Phase (2009)